DRAFT

Landsat Data Continuity Mission

Observatory Interface Requirements Document (Obs-IRD)

November 14, 2006

Revision - Draft

CM FOREWORD

This document is a Landsat Data Continuity Mission (LDCM) Project Configuration Management (CM)-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the LDCM CM Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

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Document Revision History

This document is controlled by the LDCM Project Management. Changes require approval of the LDCM Project Manager, LDCM OLI Manager, and the LDCM Mission Assurance Manager. Proposed changes shall be submitted to LDCM Systems Engineering Manager.

RELEASE	DATE	BY	DESCRIPTION
Draft	Nov.14, 2006		Initial Version

List of TBDs/TBCs/TBRs

This document contains information that is complete as possible. Items that are not yet defined are annotated with TBD (To Be Determined). Where final numerical values or data are not available, best estimates are given and annotated TBC (To Be Confirmed). If there is an inconsistency between two requirements then the best estimate is given and annotated with a TBR (To Be Resolved). The following table summarizes the TBD/TBC/TBR items in the document and supplements the revision history.

ITEM	REFERENCE	DESCRIPTION
		Data not supplied

Contents

Figures

Tables

1 SCOPE

1.1 IDENTIFICATION

This LDCM Interface Requirements Document (IRD) sets forth the general, common interface requirements imposed on both the Operational Land Imager (OLI) and Thermal InfraRed Sensor (TIRS) instruments and the spacecraft for LDCM. This IRD also include requirements that apply to the interfaces between the Instrument SSR (I-SSR) and the LDCM instruments, and between the I-SSR and the LDCM spacecraft.

1.2 APPLICABILITY

Throughout this document reference will be made to “the OLI”, “the TIRS”, “the (LDCM) spacecraft”, and “the instrument”. References to individual instruments, i.e. “the OLI” or “the TIRS” apply only to that instrument; reference to “the spacecraft” or “the LDCM spacecraft” applies only to the LDCM spacecraft; and reference to “the instrument” or “the instruments” apply equally to both the OLI and the TIRS. The I-SSR is considered an “instrument component” that is procured along with the OLI Instrument, but is a separate component from the OLI Instrument proper.

1.3 TERMINOLOGY

Throughout this document the following definitions are used:

The term *spacecraft* is interchangeable with spacecraft bus or bus, and refers to all parts of the space segment that are not the instruments.

The term *Observatory* refers to the fully or partially integrated system, including the spacecraft and one or more instruments. This term is used mainly in reference to testing to differentiate between the spacecraft bus without instruments, and the integrated satellite with instruments.

The term *instrument provider* refers to the organization / company delivering the instruments for integration on the spacecraft. The term is used interchangeably with the instrument contractor or sensor subcontractor with respect to LDCM. For the purposes of this ICD, the instrument provider is treated as a single entity, although in reality, the integrating team will probably include representatives from many organizations.

The expression ‘separately-mounted instrument components’ refers to each part of an instrument which is separately mounted onto the spacecraft by the spacecraft contractor. Where an instrument is divided into multiple pieces, but is mounted onto the spacecraft via a single baseplate, that is not considered ‘separately-mounted’ instrument components in this document.

The term "(TBD)", which means "to be determined", applied to a missing requirement means that the instrument contractor should determine the missing requirement in coordination with the spacecraft contractor.

The term "(TBS)", which means "to be specified", means that the spacecraft contractor will supply the missing information in the course of the contract. These serve as a placeholder for future requirements. The instrument contractor is not liable for compliance with these "placeholder" requirements, as insufficient information is provided on which to base a design.

The term "(TBR)", which means "to be refined/reviewed", means that the requirement is subject to review for appropriateness by both contractors, and subject to revision. The instrument contractor is liable for compliance with the requirement as if the "TBR" notation did not exist. The "TBR" merely provides an indication that the value is more likely to change in a future modification than requirements not accompanied by a "TBR".

1.4 DOCUMENT OVERVIEW

This IRD is controlled and maintained by the LDCM project office. The IRD is imposed on both the instrument contractor(s) and the spacecraft contractor, and will serve as a starting point for a detailed set of Interface Control Documents (ICD) and Mechanical Interface Drawings (MID) that will serve as the complete specification of the interfaces involved.

The following Figure 1.4-1 shows the relationship between requirements documents for the LDCM mission.

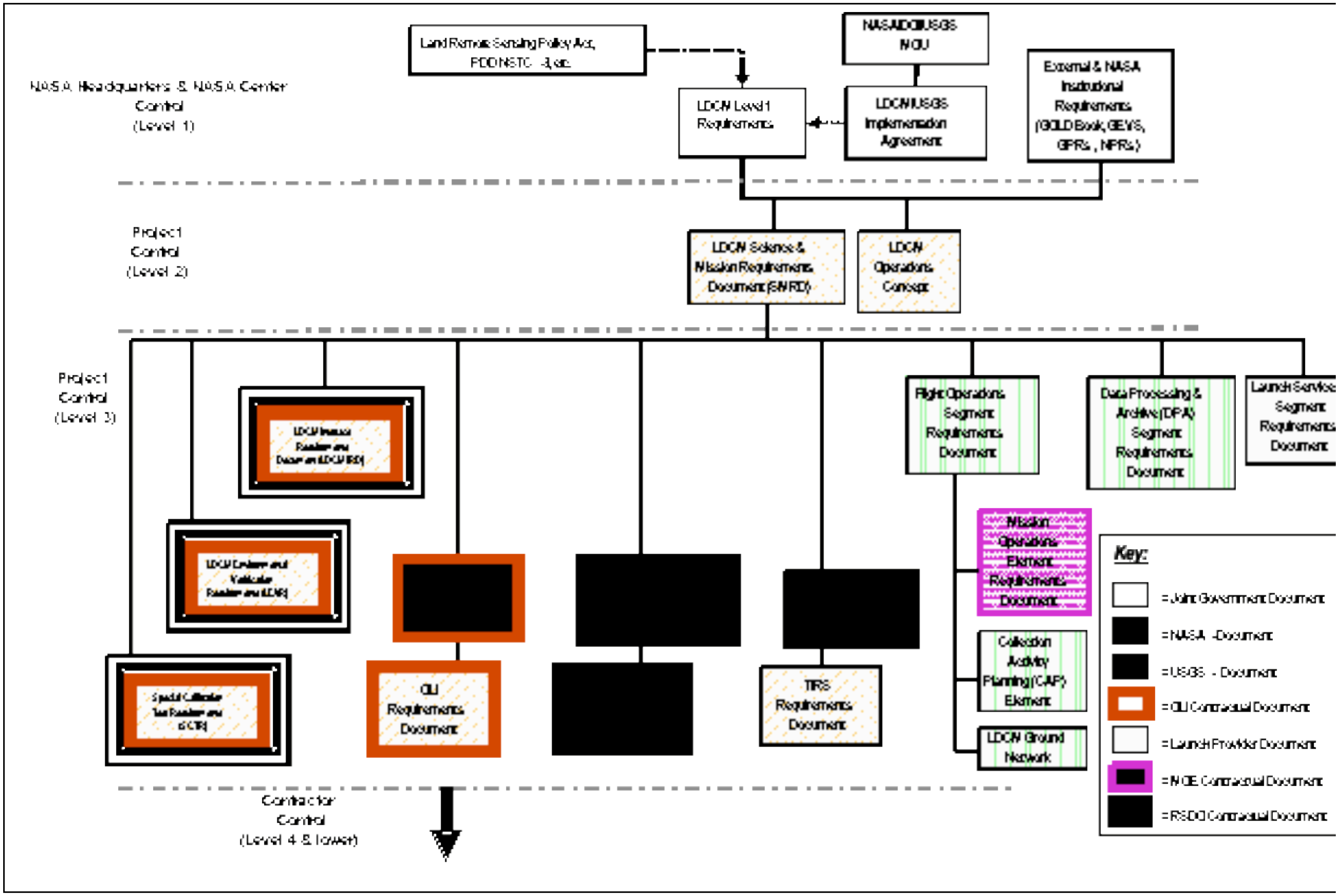

Figure 1.4-1. LDCM Requirements Tree

1.5 CONFLICTS

ICDs to more fully define the interface requirements will be generated by the various contractors during the LDCM implementation. This IRD will be rendered obsolete when all the ICDs are baselined and put under formal configuration management.

1.6 REQUIREMENT WEIGHTING FACTORS

The requirements stated in this specification are not of equal importance or weight. The following four paragraphs define the weighting factors incorporated in this specification.

a. ***Shall*** designates the most important weighting level; that is, mandatory. Any deviations from these contractually imposed mandatory requirements require the approval of the LDCM contracting officer.

b. ***Will*** designates mandatory "requirements" that are mutually agreed by the parties. Typically, *will* statements refer to tasks, including document deliveries. *Will* statements are not verified in the same manner as interfaces (e.g., analysis, inspection, test, demonstration), but by mutually agreed schedules or action items. Unless required by other contract provisions, noncompliance with the *will* paragraphs does not require approval of the contracting officer, but does require agreement by all affected parties, and does require documented technical substantiation.

c. ***Should*** designates suggestions that are requested, but are not mandatory. Unless required by other contract provisions, noncompliance with the *should* paragraphs does not require approval of the contracting officer, but does require documented technical substantiation.

d. ***May*** designates the lowest weighting level. These *may* statements designate intent and are often stated as examples of acceptable designs, items, and practices. Unless required by other contract provisions, noncompliance with the *may* paragraphs does not require approval of the contracting officer and does not require documented technical substantiation.

In the remainder of this document, those paragraphs which are intended for information or clarification, but do not represent requirements, will be shown in italics. Following such introductory text, it is possible that the same basic information may exist as a requirement, but it will be properly numbered as a requirement

2 APPLICABLE DOCUMENTS

2.1 GOVERNMENT REQUIREMENT DOCUMENTS

TBD

2.2 NON-GOVERNMENT REQUIREMENT DOCUMENTS

TBD

2.3 REFERENCE DOCUMENTS

TBD

3 OBSERVATORY INTERFACE REQUIREMENTS

3.1 GENERAL

The uncertainty, repeatability and variation values specified in this document are three (3) sigma unless specified otherwise. Ranges of values are considered not-to-exceed ranges. All other specification limits are not-to-exceed values unless specified otherwise.

3.2 SPACECRAFT TO GROUND INTERFACE REQUIREMENTS

3.2.1 S-band to Ground Interface

3.2.1.1 LANDSAT Ground Network (LGN)

3.2.1.1.1 Transmit (downlink):

Narrative of the data content (e.g. safety and housekeeping, diagnostic, etc.): TBD

Baseband data rate (nominal and maximum, if variable): TBD

Transmit frequency, bandwidth: TBD

Modulation and encoding: TBD

Ground G/T: TBD

BER required at ground: TBD

Polarization: TBD

3.2.1.1.2 Receive (uplink)

Narrative of the data content: TBD

Baseband data rate (nominal and maximum, if variable): TBD

Transmit frequency: TBD

Modulation, encoding, and encryption: TBD

Ground EIRP: TBD

BER required at spacecraft: TBD

Polarization: TBD

3.2.1.2 Space Network (SN)

3.2.1.2.1 Transmit (downlink):

Narrative of the data content (e.g. safety and housekeeping, diagnostic, etc.): TBD

Baseband data rate (nominal and maximum, if variable): TBD

Transmit frequency, bandwidth: TBD

Modulation and encoding: TBD

Ground G/T: TBD

BER required at ground: TBD

Polarization: TBD

3.2.1.2.2 Receive (uplink)

Narrative of the data content: TBD

Baseband data rate (nominal and maximum, if variable): TBD

Transmit frequency: TBD

Modulation, encoding, and encryption: TBD

Ground EIRP: TBD

BER required at spacecraft: TBD

Polarization: TBD

3.2.1.3 NASA Ground Network (GN)

3.2.1.3.1 Transmit (downlink):

Narrative of the data content (e.g. safety and housekeeping, diagnostic, etc.): TBD

Baseband data rate (nominal and maximum, if variable): TBD

Transmit frequency, bandwidth: TBD

Modulation and encoding: TBD

Ground G/T: TBD

BER required at ground: TBD

Polarization: TBD

3.2.1.3.2 Receive (uplink)

Narrative of the data content: TBD

Baseband data rate (nominal and maximum, if variable): TBD

Transmit frequency: TBD

Modulation, encoding, and encryption: TBD

Ground EIRP: TBD

BER required at spacecraft: TBD

Polarization: TBD

3.2.2 X-band to Ground Interface

The LDCM Observatory shall support up to three independent, simultaneous wideband X-band downlinks that may be a combination of one or more of the following:

a. Realtime downlink of mission data to LGN.

b. Playback of recorded mission data to LGN.

c. Realtime downlink of mission data to International Cooperators.

3.2.2.1 Landsat Ground Network (LGN)

Transmit (downlink):

Narrative of the data content: TBD

Baseband data rate (nominal and maximum, if variable): TBD

Transmit frequency, bandwidth: 8025 – 8400 MHz

Modulation and encoding: TBD

Ground G/T: TBD

BER required at ground: TBD

Polarization: TBD

3.2.2.2 International Cooperators (ICs)

Transmit (downlink):

Narrative of the data content: TBD

Baseband data rate (nominal and maximum, if variable): TBD

Transmit frequency, bandwidth: 8025 – 8400 MHz

Modulation and encoding: TBD

Ground G/T: TBD

BER required at ground: TBD

Polarization: TBD

3.3 SPACECRAFT TO INSTRUMENT INTERFACE REQUIREMENTS

The system interfaces relevant to the instruments are depicted in Figure 3.3-1. They are defined here in terms of the mechanical and electrical requirements.

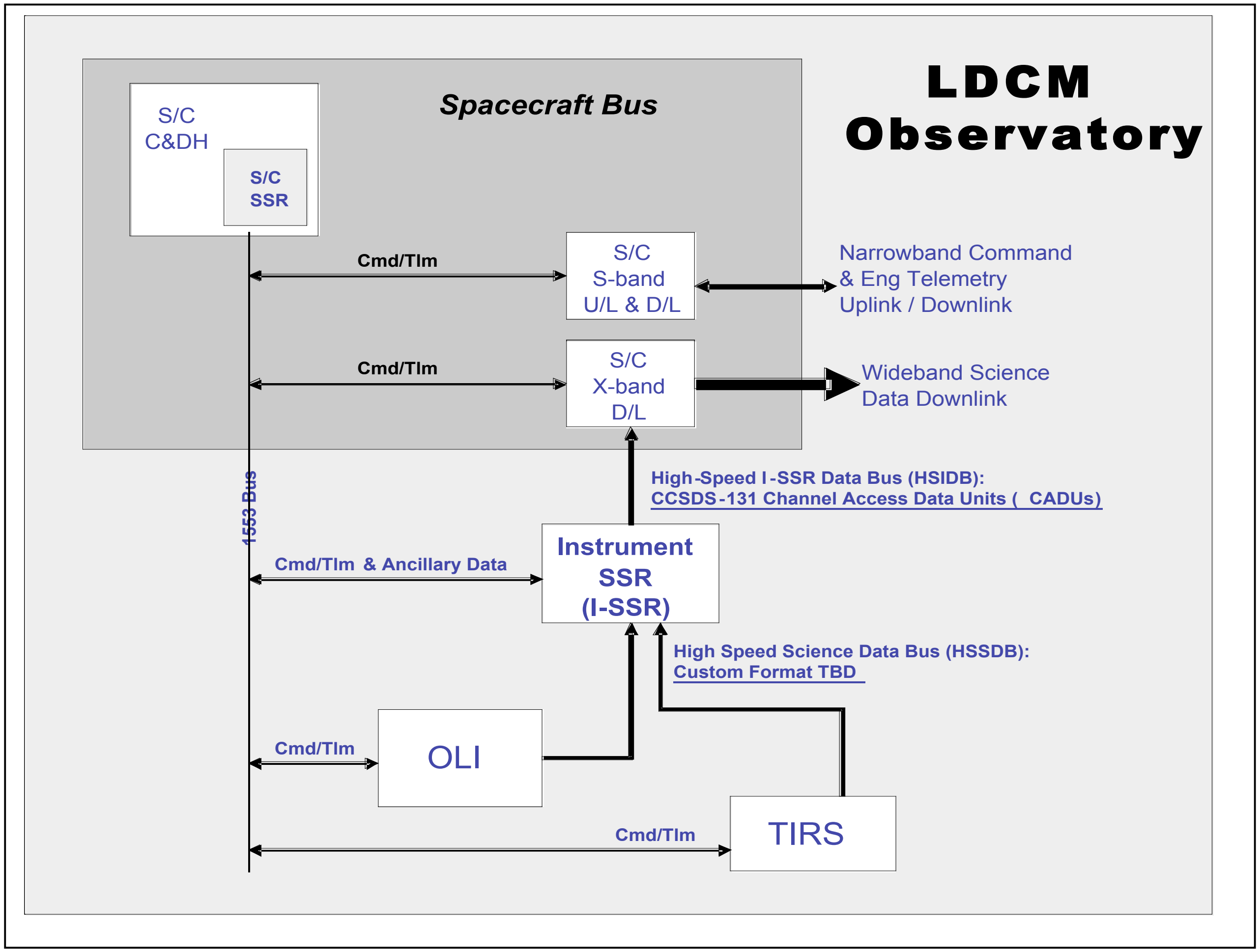

Figure 3.3-1. Spacecraft to Instrument Command, Telemetry and Data Interfaces

3.3.1 Mechanical Interface Requirements

All mechanical requirements specified shall be met at the mechanical interface; that is, at the surface(s) of the spacecraft where the instrument is in contact with the spacecraft, unless otherwise specifically indicated.

Where kinematic mounts are used, the mechanical interface is the surface of the mount that contacts the spacecraft optical bench.

3.3.1.1 Dimensions

All interface documents shall use metric units. An exception is allowed for interface documents in native imperial units. The metric units shall be displayed above the converted units with the imperial units in parentheses.

Dimensioning shall be in the as-designed units, and identified when other than SI.

Analysis results produced by existing software tools may be in heritage units.

The design of the instrument shall meet the dimensional envelope constraints defined in the ICD under a combination of static, dynamic, and thermal conditions encountered during factory assembly, system test, transportation and handling, launch, deployment, and on-orbit operations.

3.3.1.2 Reference Frames

3.3.1.2.1 Observatory Reference Frame

Reference Ellipsoid: The WGS 84 reference ellipsoid as defined by NIMA TR8350.2.

Nadir: Defined at any point in the orbit as the direction toward the center of mass of the Earth.

Inertial Velocity: The velocity relative to the ECI (J2000.0) reference frame.

The LDCM Orbital Reference Frame shall be a right-handed, orthogonal, XYZ coordinate system defined such that the origin is at the spacecraft center of mass (CM), the +Z axis points toward Nadir, the +X axis is coplanar with both the +Z axis and the spacecraft inertial velocity vector (and is in the general direction of the spacecraft inertial velocity vector), and the +Y axis completes the right-handed, orthogonal coordinate system as shown in Figure 3.3.1.2.1-1.

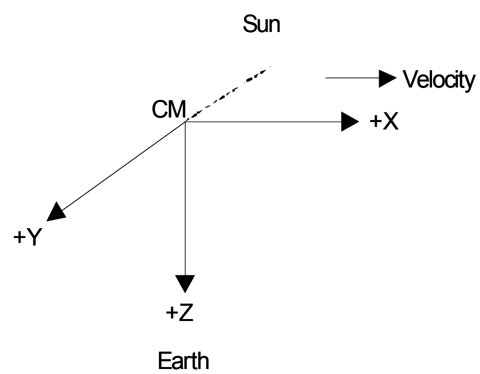

Figure 3.3.1.2.1-1 Orbital Reference Frame

3.3.1.2.2 Spacecraft Body Frame

The LDCM Spacecraft Body Frame shall be a right-hand, orthogonal, body-fixed XYZ coordinate system with the +Z direction pointing to nadir.

The associated mechanical datums and origin shall be described in the MID.

3.3.1.3 Instrument Fields of View

3.3.1.3.1 OLI Fields of View

3.3.1.3.1.1 Unobstructed Field of View

The LDCM spacecraft shall provide an unobstructed minimum nadir field of view for OLI that provides a 15.0 degree cross track width by at least 1.7 degree along track length for any OLI optical aperture location that falls within the X-Y dimension constraints of the instrument.

The boresight of the unobstructed field of view shall be parallel to the nadir (+Z) axis.

3.3.1.3.1.2 Glint-Free Field of View

The LDCM spacecraft shall provide the OLI an unobstructed FOV within a conical 25° (TBR) half angle of optical nadir for any OLI optical aperture location that falls within the X-Y dimension constraints of the instrument aperture.

The cone's circular intersection on the +Z face shall envelope the oval-shaped nadir port aperture.

3.3.1.3.1.3 Unobstructed Solar Calibration Field of View

The LDCM spacecraft shall provide the OLI with a solar calibration field of view unobstructed by spacecraft structures for any time of the year across a range of solar elevation angles from -15° to -25° **(TBR)** relative to the local horizontal for the post eclipse exit portion of the orbit.

To cover the seasonal variation in the solar azimuthal position, the clear solar calibration field of view for the indicated solar elevation range shall be 38°± 8° (TBR) in azimuth towards the sun side from the velocity vector for the post eclipse exit portion of the orbit.

3.3.1.3.1.4 Glint-Free Solar Calibration Field of View

The LDCM spacecraft shall provide the OLI an unobstructed FOV within a region bounded by –10 to –30° **(TBR)** in elevation and 38°± 60° (TBR) in azimuth (towards the sun side) from the edges of the solar calibration port.

The bounding surface of this region's intersection with the instrument shall envelope the rectangular shaped solar calibration aperture. The spacecraft contractor shall accommodate this FOV except for the obstructions shown in Figure 3-3.

3.3.1.3.2 TIRS Fields of View

TBD

3.3.1.4 Mass Properties

In the paragraphs below, the term "actual" refers to values which apply to a given serial number. As indicated below, these are generally provided in a data package associated with delivery of each individual serial numbered instrument.

The terms "typical" and "predicted" are used to document a nominal value in the ICD. These may be the result of calculations or measurements on a non-flight unit which is expected to be representative of the value for a flight unit.

3.3.1.4.1 Mass Allocation

3.3.1.4.1.1 OLI Mass Allocation

The total mass of the OLI and all associated hardware and harnessing shall not exceed 350 kg (TBR).

The mass of the OLI shall be measured to an accuracy of ± 0.1 kg at delivery to the spacecraft.

3.3.1.4.1.2 TIRS Mass Allocation

The total mass of the TIRS and all associated hardware and harnessing shall not exceed 200 kg (TBR).

The mass of the TIRS shall be measured to an accuracy of ± 0.1 kg at delivery to the spacecraft.

3.3.1.4.1.3 I-SSR Mass Allocation

The total mass of the I-SSR and all associated hardware and harnessing shall not exceed 90 kg (TBR).

The mass of the I-SSR shall be measured to an accuracy of ± 0.1 kg at delivery to the spacecraft.

3.3.1.4.2 Center of Mass

3.3.1.4.2.1 Center of Mass Location

The typical launch and on-orbit center of mass of each separately mounted instrument component shall be documented in the MID, referenced to the instrument coordinate axes.

The actual stowed (launch) and deployed (on-orbit) centers of mass of each separately-mounted instrument component shall be measured by the instrument contractor, reported to ± 6 mm (not-to-exceed), referenced to the instrument coordinate axes and documented in the data package for that serial number instrument.

The instrument coordinate axes shall be defined to be in the same orientation as the spacecraft axes, but not necessarily the same origin.

3.3.1.4.3 Moments and Products of Inertia

The moments and products of inertia shall be measured or calculated for each separately-mounted instrument component, using coordinates based on the spacecraft axes but passing through the instrument component center of mass.

These moments and products of inertia shall be provided to the spacecraft contractor for documentation in the ICD.

3.3.1.4.3.1 Moments and Products of Inertia Accuracy

Moments and products of inertia values shall be accurate to within ± 5 % for calculated values, and the lesser of 5% or 300 kg-cm_ for measured values.

3.3.1.4.3.2 Moments and Products of Inertia Variation Documentation

If the instrument contains movable masses, expendable masses, or deployables, the typical respective moments and products of inertia variations during the deployment, specified at least at the beginning, middle, and end of the deployment, shall be provided to the spacecraft contractor for documentation in the ICD.

If an instrument contains movable masses or deployable items, the respective moments and products of inertia variations shall be measured or calculated and documented in the delivered data package.

3.3.1.5 Stowed and Critical Clearances

Both the spacecraft contractor and the instrument contractor must work together to insure that the stowed, deploying, and final deployed positions of the instrument will clear all obstacles, including obstacles on the spacecraft, other instruments, and the launch vehicle.

The instruments shall fit within the static envelope of launch vehicle's fairing.

Instrument components in all configurations shall be contained within the instrument envelopes as allocated within the MID, but different envelopes may be defined for launch configuration, on-orbit (deployed) configuration, and during deployment.

The defined not-to-exceed envelope includes, but is not limited to, the basic instrument structure, instrument-unique mounts (including kinematic mounts, where used), instrument-unique mounting hardware, mounting feet, thermal blankets (including billowing during launch and ascent), connectors (instrument-side only), and intra-instrument harness (with connectors), as well as any other items that constitute any part of a deliverable instrument.

The intent of this requirement is that everything provided as part of a deliverable instrument, including the items identified above, be allocated against the instrument size and weight allocations, and that everything provided by the spacecraft contractor be held against the spacecraft allocation.

The instruments shall be laid out on the spacecraft so as to maintain adequate clearance between the instrument and surrounding structures, in order to provide access to instrument mounting hardware, access to instrument connectors, and space for instrument interfacing harness service loops.

3.3.1.6 Documentation in MID

The instrument subsystem envelope (including thermal blankets, instrument connectors, mounting feet, instrument-supplied harnesses, and unique mounts) will be documented in the MID.

Documentation is to be in the form of engineering drawings with a set of "not to exceed" dimensions for the launch, deployed on-orbit, and installation envelopes. The instrument installation envelope is defined as the volume of the instrument including the attached lifting sling.

All instrument fields of view, including, where applicable, optical, glint, thermal cryo-radiator, electronics radiator, and solar diffuser fields of view, will be documented in the MID.

Information on field-of-view-related issues such as clearances, multi-path tolerances, indirect effects such as glint and allowable secondary radiation, and percent interference allowed will be documented in the MID.

3.3.1.7 Mounting Provisions

3.3.1.7.1 Instrument Optical Bench

The spacecraft shall provide an optical bench as the mounting surface for the TIRS and OLI instruments.

3.3.1.7.2 Instrument Structural Support

The spacecraft shall provide structural support for the instruments such that the loads transmitted through the optical bench and across the interface into the instruments do not exceed the interface limit loads determined by the spacecraft contractor.

3.3.1.7.3 I-SSR Accommodation

The I-SSR shall not be mounted on the instrument optical bench.

The I-SSR shall be mounted on or within the main spacecraft structure.

The spacecraft shall provide the thermal path for all I-SSR heat rejection.

3.3.1.7.4 Mounting Method

The mounting method shall accommodate manufacturing tolerance, structural distortion, thermal distortions, and alignment requirements.

The spacecraft to instrument mounting interface will be established by the spacecraft contractor from the instrument provided drill template and shown in the MID. This process aligns the instrument mechanical datums to the spacecraft body frame within the spacecraft alignment control allocation precluding the need to shim or correct the instrument orientation at instrument installation.

If required, the spacecraft contractor will provide contingency shims to correct instrument alignment control error at installation. Shim capability for out of plane rotations (spacecraft X & Y axis) will be limited by pin / bolt clearance. There is no adjustment capability for in plane rotation (about spacecraft Z axis) where close fit pins are used.

Potential mounting interface gaps (prior to fastener full preload) will be managed through instrument, spacecraft, and drill template flatness and / or co-planarity requirements to preclude the need to shim for gaps at installation.

If required, the spacecraft contractor will provide contingency shims to close gaps at installation. Shim capability will be limited by pin / bolt clearances and access required to inspect or perform gap measurements.

The instrument mounting method shall require access only from outside the spacecraft.

Specific requirements for pinning the instrument, if required, will be documented in the MID.

3.3.1.7.5 Mounting Interface

3.3.1.7.5.1 Mounting Interface Documentation

The spacecraft mounting interface requirements for each separately-mountable instrument component shall be defined in the MID.

3.3.1.7.6 Drill Templates

3.3.1.7.6.1 Drill Template Usage

The drill template is used during the manufacturing of the spacecraft bus to establish instrument interface features. The drill template is supported from a gantry (mechanical ground support equipment). The template/instrument mounting datum features are aligned to the spacecraft body frame with laser tracker and/or theodolite measurements. With the template properly aligned, spacecraft secondary structure is matched to the template through a combination of drill, bolt, and bonding processes as required.

The drill template may also be used for interface and alignment verification during the spacecraft manufacturing and AI&T phases.

If templates are used, then instrument equipment, spacecraft, and test fixture interfaces shall be established using the same templates (i.e. face to face master).

3.3.1.7.6.2 Drill Template Fabrication Requirements

Drill template design features (including, but not limited to surface flatness, surface finish, surface treatment, etc.) will be documented in the MID.

The material shall be aluminum (preferred), steel or other suitable material.

Drill templates for each component that require alignment shall include an optical alignment target or cube bonded to the template.

Optical alignment target / cube nominal location and orientation with respect to mounting datum(s) will be as shown on MID.

Optical alignment target / cube nominal location and orientation with respect to mounting datum(s) shall be similar to instrument.

3.3.1.7.7 Mounting Hardware

3.3.1.7.7.1 Mounting Hardware Provider

The instrument contractor will provide all unique instrument mounting hardware (e.g., bolts, washers, etc. which have limited-off-the-shelf availability or require a special fabrication lot).

The spacecraft contractor will provide all standard instrument mounting hardware (e.g., bolts, washers, shims, etc. which are procurable off-the-shelf from multiple hardware vendors).

3.3.1.7.7.2 Mounting Hardware Documentation

Instrument mounting hardware will be defined and documented in the MID, including indication of the source of the hardware (spacecraft or instrument).

3.3.1.7.7.3 Mounting Hardware Delivery

Delivery of mounting hardware with the instrument will be accomplished with each separately-mounted or attached element to be separately kitted.

Each unique hardware type or size will be separately packaged and clearly identified with its relationship to the instrument top assembly drawing.

3.3.1.7.7.4 Mounting Surface Requirements

Finish requirements for the mounting surfaces will be specified by the spacecraft contractor and documented in the MID.

The spacecraft mounting surface flatness shall be as documented in the MID.

The instrument mounting surface flatness shall be as documented in the MID.

The spacecraft mounting surface planarity shall be as documented in the MID.

The instrument mounting surface planarity shall be as documented in the MID.

3.3.1.7.8 Mounting Location and Documentation

The instrument contractor will support the spacecraft contractor in determining the location of the instrument on the spacecraft.

The instrument contractor will provide necessary mounting information to the spacecraft contractor for documentation in the MID.

The instrument mounting location will be documented in the MID.

3.3.1.7.9 Special Mounts

Instrument components shall be mounted using kinematic mounts unless the instrument contractor determines that kinematic mounts are not required.

The instrument will be delivered to the spacecraft contractor with the flight kinematic mount installed.

3.3.1.8 Orbit Control, Pointing and Alignment

Pointing: The process of controlling the location or direction of a Line of Sight with respect to an intended target location or direction.

Instrument Interface: The mechanical interface and associated datum(s) at the location where the instrument attaches to the spacecraft.

Jitter: Rotations due to elastic as well as rigid body vibrations caused by disturbance sources such as reaction wheels, solar array drive assemblies and instrument mechanisms.

Spacecraft Attitude Determination Frame: The right-handed orthogonal reference frame which approximates the Spacecraft Body Frame and of which the Attitude Determination System on board the spacecraft determines inertial attitude. For LDCM, the datums associated with the Spacecraft Control Frame are (TBS). The Spacecraft Attitude Determination Frame is defined by the relative orientation of these datums with respect to the Spacecraft Body Frame, as established by measurements during installation alignment or on-orbit calibration.

Spacecraft Target Frame: The right-handed, orthogonal reference frame that, at any time, is the target attitude of the Spacecraft Attitude Determination Frame.

3 Sigma: A set of values is considered to meet a 3 sigma requirement if no fewer than 99.73% of the values are within the specified limits of the requirement.

Root Sum Square (RSS): The square root of the sum of the squares of components of error or uncertainty.

Alignment: The relative orientation of 2 reference frames.

Installation Alignment: The process of setting, measuring and/or adjusting the relative orientation of an instrument or hardware reference frame with respect to another reference frame in order to satisfy required alignment criteria.

Alignment Shift: A change in the alignment between 2 reference frames that occurs over one finite, defined, period of time, typically prior to and not changing significantly during normal on-orbit operations. For the alignment of the instruments relative to the spacecraft, alignment shifts arise from structural distortion effects such as launch loads, moisture out-gassing and the relief of gravity loads.

Alignment Drift: Changes in the alignment between 2 reference frames that occur during normal on-orbit operations, excluding effects due to jitter. For the alignment of instruments relative to the spacecraft, one source of drift is structural distortions arising from orbital and seasonal changes in thermal conditions.

Alignment Knowledge: The estimate of the relative orientation between 2 reference frames.

Alignment Knowledge Uncertainty: The uncertainty in the knowledge of the relative orientation between 2 reference frames.

Boresight Alignment Knowledge Uncertainty: For a specific instrument, the uncertainty in the knowledge of the relative orientation between its Instrument Boresight and the Spacecraft Attitude Determination Frame. This uncertainty will be considered to be composed of the following factors:

- *Static (not changing significantly during normal on orbit operations)*

    Measurement uncertainty during installation alignment.

    Alignment Shifts.

- *Dynamic (changing significantly during normal on orbit operations)*

    Alignment Drifts.

    Jitter.

Alignment Control: The process of controlling the maximum difference between the actual orientation of a reference frame and its nominal orientation.

Alignment Control Error: The maximum difference between the actual orientation of a reference frame and its nominal orientation.

Boresight Alignment Control Error: For a specific instrument, the maximum difference between the actual and the nominal orientation of its Instrument Boresight relative to the Spacecraft Attitude Determination Frame. This error will be considered to be composed of the following factors:

- *Static (not changing significantly during normal on orbit operations)*

    Measurement uncertainty during installation alignment.

Limitations associated with fabrication and installation.

Alignment Shifts.

- *Dynamic (changing significantly during normal on orbit operations)*

Alignment Drifts.

Jitter.

Figures 3.3.1.8.-1, 3.3.1.8.-2, and 3.3.1.8.-3 illustrate a framework for representing the train of components of Knowledge Uncertainty and Control Error between an Instrument Boresight and inertial references.

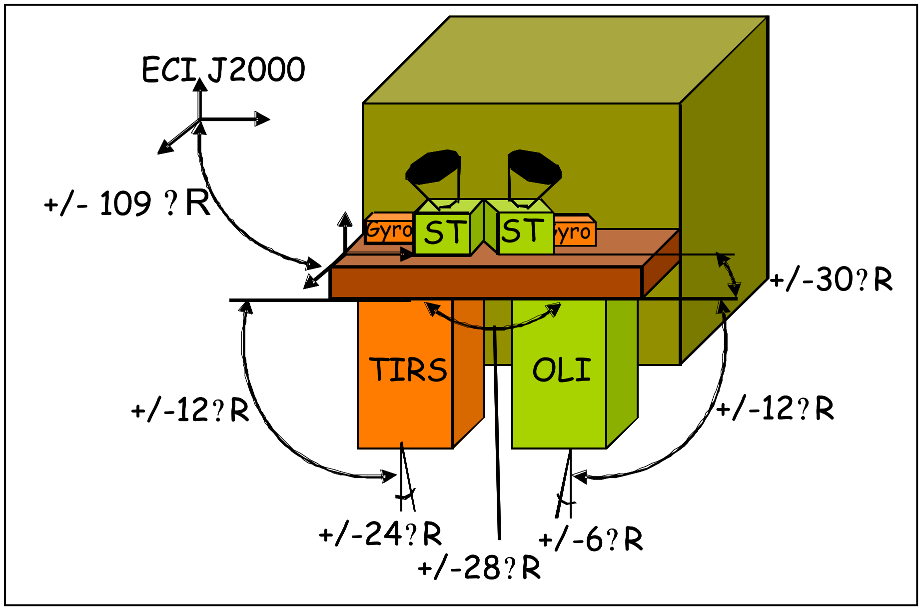

Figure 3.3.1.8-1. Spacecraft/Instrument Allocation of Knowledge (TBR)

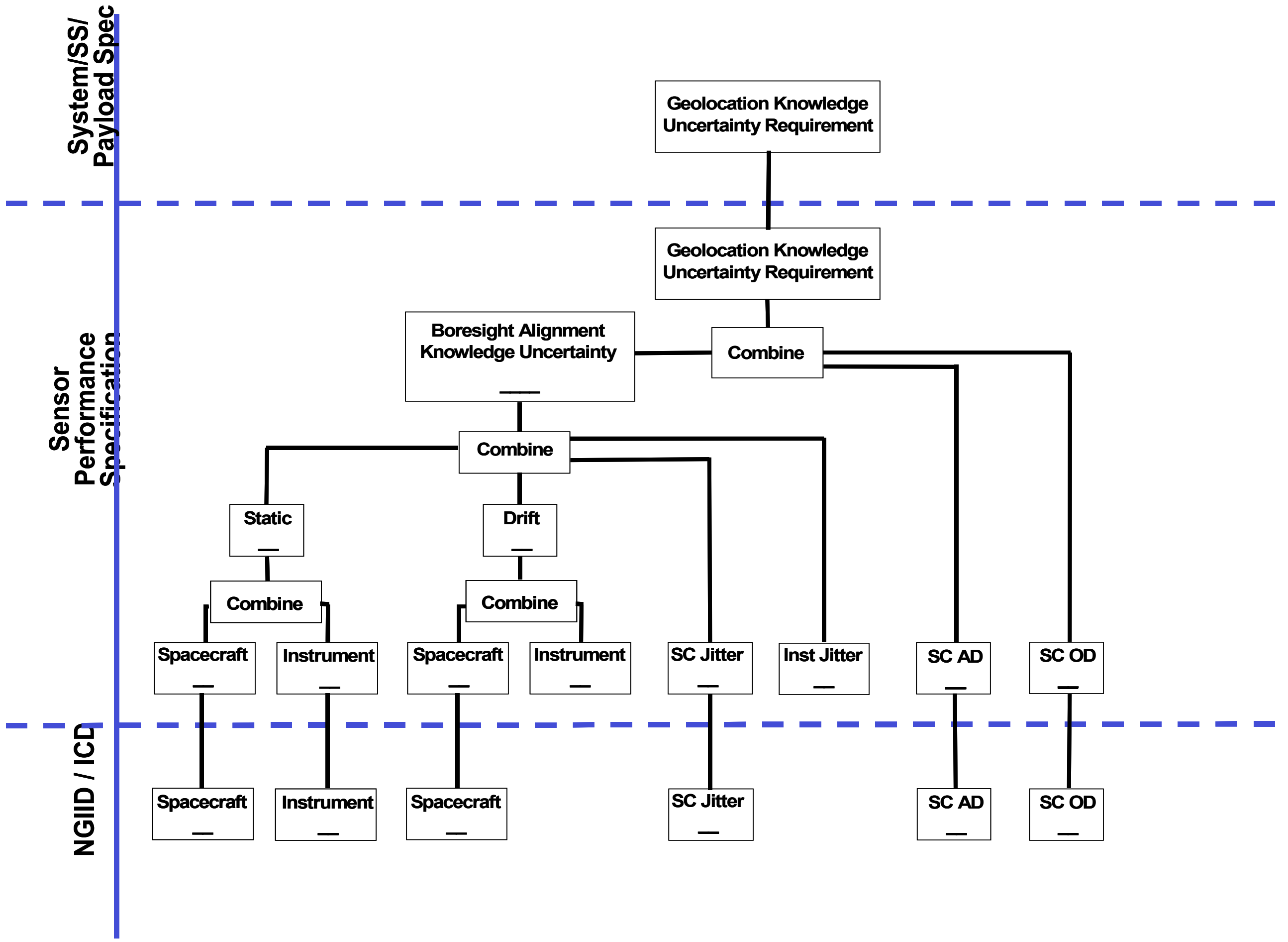

Figure 3.2.4.2.3.3-2 Spacecraft / Instrument Allocation of Geolocation Knowledge Uncertainty

Figure 3.3.1.8-2. Spacecraft / Instrument Allocation of Geolocation Knowledge Uncertainty

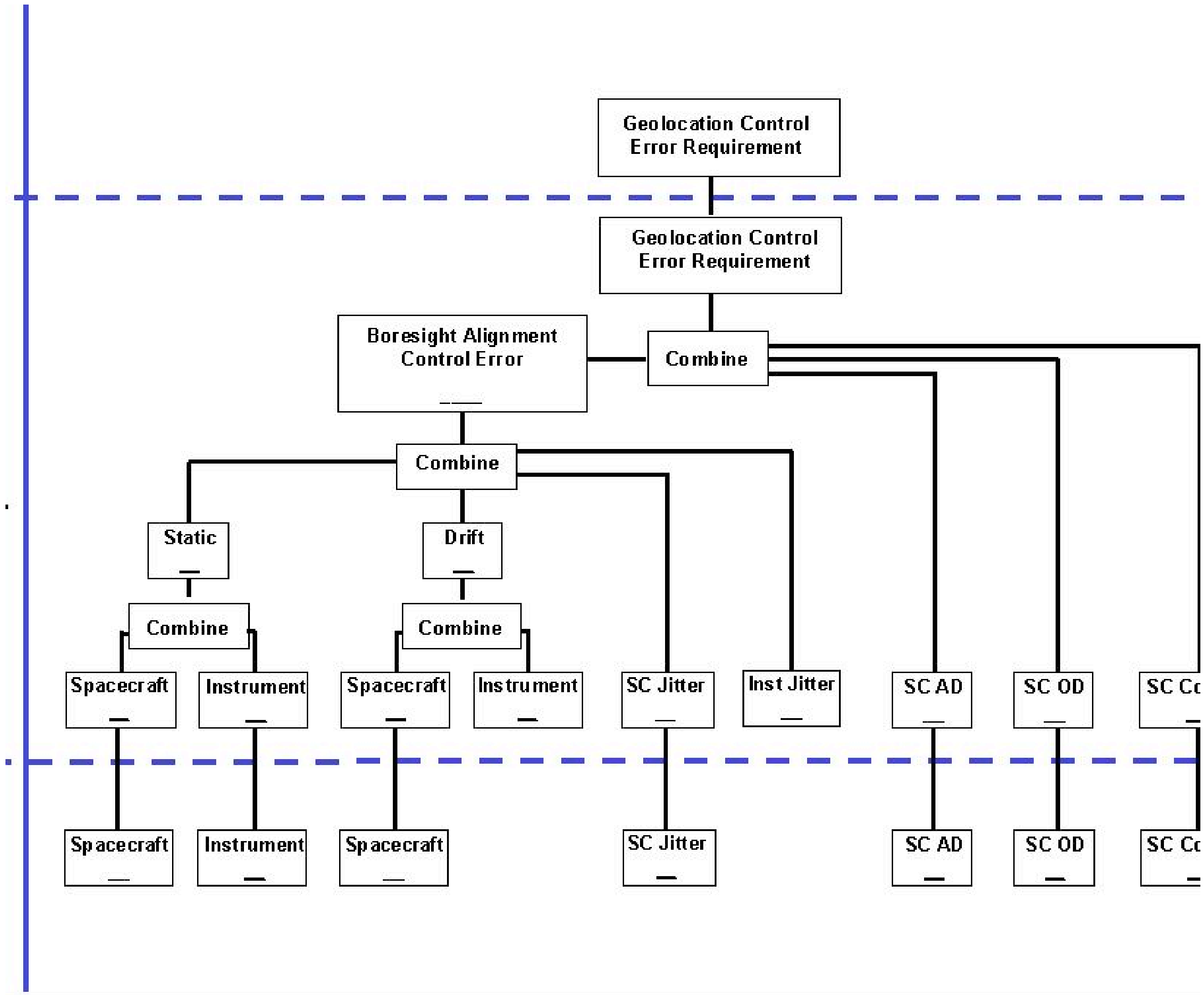

Figure 3.3.1.8-3. Spacecraft / Instrument Allocation of Geolocation Control Error

3.3.1.8.1 Orbit Control

3.3.1.8.1.1 Spacecraft State Knowledge

The spacecraft shall supply to the ground an estimate of Spacecraft position and velocity for ground processing.

The spacecraft shall use the International Atomic Time (TAI) time as the observatory time reference.

The spacecraft shall provide the orbital position and velocity in the WGS84 Earth Centered Earth Fixed coordinate frame.

The spacecraft shall provide an estimate of position and velocity time-tagged to an accuracy of 200.0 microseconds [TBC], 3-sigma, or less, with a frequency of at least once per second.

The spacecraft shall provide orbital position knowledge accurate to 30 m [TBR] radial, 30 m [TBR] in-track, and 30 m [TBR] cross-track – all values are 3-sigma.

The spacecraft shall provide orbital velocity knowledge accurate to 0.3 m/sec [TBR] radial, 0.3 m/sec [TBR] in-track, and 0.3 m/sec [TBR] cross track – all values are 3-sigma.

3.3.1.8.2 Pointing

3.3.1.8.2.1 Spacecraft Attitude Knowledge

The spacecraft shall supply to the ground an estimate of Spacecraft attitude for ground processing.

The spacecraft shall provide the attitude estimate as a quaternion relative to the Earth Centered Inertial of epoch J2000.0 coordinate frame.

The spacecraft shall provide inertial attitude knowledge of the instrument mounting surface with an accuracy of 109 micro-radians, 3-sigma, per axis, for each instrument during imaging.

The spacecraft shall provide an estimate of the inertial attitude knowledge time-tagged to an accuracy of 200.0 microseconds [TBC], 3-sigma, or less, with a frequency of at least once per second.

The spacecraft shall provide relative inertial attitude knowledge accuracy over a 30 second period of 11 micro-radians or less, 3-sigma, per axis, during imaging.

The spacecraft shall provide relative inertial attitude knowledge accuracy over a 2.5 second period of 5 micro-radians or less, 3-sigma, per axis, during imaging.

The spacecraft shall supply to the ground the attitude and/or attitude rate measurements provided by the attitude determination sensors, at the full attitude sensor data rate, for ground processing.

3.3.1.8.2.2 Spacecraft Attitude Control

During normal operation, the Spacecraft Attitude Control Error is the difference between the orientation of the Spacecraft Target Frame and the orientation of the Spacecraft Attitude Determination Frame. During normal operation, the Spacecraft Attitude Control Rate Error is the difference between the angular rate of the Spacecraft Target Frame and the angular rate of the Spacecraft Attitude Determination Frame.

The LDCM Observatory pointing reference shall be with respect to the Local Vertical / Local Horizontal reference frame.

The spacecraft shall limit pointing control error to less than 525 micro-radians [TBR], 3-sigma, per axis, during imaging periods.

The spacecraft shall limit pointing rate error to less than 145 micro-radians [TBR] / sec, 3-sigma, per axis, during imaging periods.

3.3.1.8.2.3 Jitter Sources

The spacecraft shall limit the high frequency disturbances from all sources applied to the instrument interface to no greater than TBD, 3-sigma, per axis, during imaging.

3.3.1.8.3 Alignment

3.3.1.8.3.1 Installation Alignment Responsibilities

The instrument contractor shall provide an Instrument Alignment Reference(s) composed of an alignment target or cube with associated alignment data relative to the Instrument Boresight and the mounting surface datum(s) associated with the instrument.

The spacecraft contractor will provide a Spacecraft Alignment Reference(s) composed of an alignment target or cube with associated alignment data relative to the Spacecraft Body Frame.

The alignment data for the Instrument Boresight relative to the Instrument Alignment Reference(s) will be provided to the spacecraft contractor 6 months prior to the delivery of the instrument.

The process for verifying gaps will be documented in the MID.

The spacecraft contractor will measure the alignment between the Instrument Alignment Reference and the Spacecraft Alignment Reference.

3.3.1.8.3.2 Installation Alignment References

The Instrument Alignment References shall be viewable from two orthogonal directions when integrated to the satellite.

The type, location, and orientation of the Instrument Alignment References will be mutually agreed upon between the instrument contractor and the spacecraft contractor, and documented in the MID.

Optical targets or cubes shall have a per-face surface area of at least 360 mm2.

At least two viewing surfaces of the optical alignment target or cube shall be orthogonal to within ± 15 micro-radians, 3 sigma.

Each optical target or cube shall be covered with a flight quality (and flight capable) cover.

The optical cube cover shall be removable during Integration and Test.

The optical cube cover shall be installed prior to integration onto the launch vehicle.

The cover shall provide captive hardware to prevent loose pieces if the cube comes loose.

3.3.1.8.3.3 Alignment Knowledge

All components of Boresight Alignment Knowledge Uncertainty between the Spacecraft Attitude Determination Frame and the Instrument Interface (mounting surface datums) will be allocated to the spacecraft.

All components of Boresight Alignment Knowledge Uncertainty between the Instrument Interface (mounting surface datums) and the Instrument Boresight will be allocated to the instrument.

Components of Boresight Alignment Knowledge Uncertainty resulting from alignment shifts allowed by clearances across the mounting interface (pin/fastener to hole tolerance) at the Instrument Interface (mounting surface datums) will be allocated to the instrument.

3.3.1.8.3.4 Alignment Control

All components of Boresight Alignment Control Error between the Spacecraft Attitude Determination Frame and the Instrument Interface (mounting surface datums) will be allocated to the spacecraft

For each instrument, the Boresight Alignment Control Error will be controlled by an allocation from the Instrument Boresight to the Instrument Interface mechanical datums, as well as an allocation from the Instrument Interface mechanical datums to the Spacecraft Attitude Determination Frame.

For each instrument, the Boresight Alignment Control Error allocations will be documented in the instrument ICD.

All components of Boresight Alignment Control Error between the Instrument Boresight and the Instrument Interface (mounting surface datums) will be allocated to the instrument.

Components of Boresight Alignment Control Error resulting from alignment shifts allowed by clearances across the mounting interface (pin/fastener to hole tolerance) at the Instrument Interface (mounting surface datums) will be allocated to the instrument.

3.3.1.8.3.5 Alignment Stability

The spacecraft shall maintain alignment stability of 9 microradians or less, from the OLI mounting interface to the observatory attitude reference, over any period of 30 seconds.

The spacecraft shall maintain alignment stability of 30 microradians or less, from the OLI mounting interface to the observatory attitude reference, over any period of 16 days.

The spacecraft shall maintain alignment stability of 28 (TBR) microradians or less, from the TIRS mounting interface to the OLI mounting interface, over any period of 16 days.

3.3.2 Thermal Interface Requirements

3.3.2.1 General

The operating and survival temperatures, as well as the thermal isolation requirements specified in this section shall be met at the mechanical interface between the spacecraft and the instrument.

The instrument thermal design shall provide for utilizing spacecraft survival bus power for maintaining the instrument at or above the minimum survival temperature when the instrument is off (including launch configuration) and at or above the minimum turn-on temperature before the instrument is activated.

3.3.2.2 Thermal Recovery

The instrument shall take no more than 60 [TBR] minutes to return from SAFE mode to a temperature condition capable of normal operation, assuming no anomalies.

This time limitation does not include passive radiative detector coolers.

The instrument shall take no more than 120 [TBR] minutes to return from SURVIVAL mode to a temperature condition capable of normal operation, after spacecraft application of operational power.

This time limitation does not include passive radiative detector coolers.

3.3.2.3 Instrument Thermal Fields of View

Note: Thermal analysis will verify the heat transfer adequacy at the final mounting locations. Details of adjacent hardware within the instruments' thermal FOV shall be provided by the spacecraft to a mutually agreed upon level of fidelity.

3.3.2.3.1 OLI Thermal Fields of View

3.3.2.3.1.1 OLI Thermal FOV

The spacecraft shall provide to the cold face of the OLI a minimally obstructed hemispherical FOV for heat dissipation.

3.3.2.3.2 TIRS Thermal Fields of View

The spacecraft shall provide to the cold face of the TIRS a minimally obstructed hemispherical FOV for heat dissipation.

3.3.2.4 Heat Transfer

The instrument modules shall be thermally isolated to the maximum extent possible to minimize heat transfer to the spacecraft and other adjacent instruments.

To maintain flexibility in the placement of instrument modules on the spacecraft, it is necessary to limit the total heat transfer (conduction and radiation) to the spacecraft and other instruments. The thermal isolation is accomplished by minimizing thermal conduction and radiation using low thermal conductivity mechanical interface mounts and low effective emissivity MLI blankets at all non-radiator instrument surfaces. Radiation to the earth or to cold space is intended to be the primary means of dissipating waste heat from the instrument.

The total orbit-average heat transfer rate (conducted and radiated) between the instrument and the spacecraft shall not exceed 10 watts into or out of the instrument mounting surface.

This includes heat conducted through the harness and ground straps.

Each instrument module total orbit average heat transfer rate (conducted and radiated) between the instrument and the spacecraft, divided by the footprint area, shall not exceed 15 watts per square meter into or out of the instrument.

This includes heat conducted through the harness and ground straps.

The term 'footprint area" as used in this requirement means the area under the instrument module, projected onto the spacecraft. It does not refer to the area of the footprint of the kinematic mounts.

3.3.2.5 Temperature

Temperature limits for instrument components during ground test and orbital operations shall be provided by the instrument contractors to the spacecraft contractor for documentation in the ICD.

Turn-on temperature requirements, relative to the passive analog temperature sensors, shall be provided by the instrument contractors to the spacecraft contractor for documentation in the ICD.

3.3.2.5.1 Spacecraft Mounting Interface Temperature Requirements

In normal operational mode, the spacecraft shall maintain the temperature of the mechanical instrument-to-spacecraft mounting surface within the range specified in the ICD.

The instrument shall meet all specified performance requirements when the temperature of the mechanical instrument-to-spacecraft mounting surface is in the normal operating range.

The interface on the LDCM spacecraft shall remain in the range specified in the ICD during survival mode.

3.3.2.5.2 Temperature Monitoring

The location of the spacecraft-provided interface temperature monitoring sensors will be shown in the MID.

The location of all instrument contractor-supplied temperature sensors and calibration data will be provided to the spacecraft contractor for documentation in the MID.

3.3.2.5.2.1 Mechanical Mounting Interface Temperature Monitoring

The spacecraft shall monitor and report the temperatures of the spacecraft at the instrument mechanical mounting interfaces in the spacecraft telemetry.

3.3.2.5.2.2 Instrument Temperature Monitoring

All critical instrument temperatures shall be reported by the instrument in the health and status telemetry data.

3.3.2.6 Thermal Control Design

3.3.2.6.1 Thermal Control Hardware

The instrument contractor will provide to the spacecraft contractor information on instrument-provided thermal control hardware for documentation in the ICD

The responsibility for providing the thermal control hardware is defined in Table 3.2.4.7.6.1-1.

Table 3.3.2.6.1-1. Thermal Control Hardware Responsibility

Hardware	Responsibility
Survival heaters	Instrument Contractor

Hardware	Responsibility
Instrument thermal control hardware, including blankets, louvers, and heat pipes	Instrument Contractor
Instrument-to-spacecraft interface operational and survival heaters, thermistors, thermostats	Spacecraft Contractor
Thermal close-out blankets to interface between the instrument thermal blankets and the spacecraft thermal blankets	Spacecraft Contractor
Instrument-to spacecraft interface MLI blankets	Spacecraft Contractor

3.3.2.6.2 Survival Heaters

Instruments shall utilize survival heaters to maintain temperatures at or above minimum survival limits, when the operational power bus has been disconnected from the instrument.

Survival heaters shall not be required to provide heat when the operational bus is active to the instrument.

In agreement with the instrument contractor, the spacecraft contractor may elect to leave the survival heater bus powered during the initial phase of warm-up upon exit from SURVIVAL mode, but the instrument must be capable of achieving thermal control, once the operational power bus is activated, without use of the survival heaters.

3.3.2.6.3 Operational Heaters

When the instrument operational power bus is active, operational heaters located inside the instrument, and controlled by the instrument, shall be used for normal thermal control.

3.3.2.6.4 Multilayer Insulation

The spacecraft contractor is responsible for approving the Multilayer Insulation (MLI) selection in the Parts, Materials and Processes Control Board (PMPCB) review process.

MLI used in thermal control design shall have the following provisions: venting, interfacing with spacecraft thermal control surfaces, and electrical grounding to prevent Electro-Static Discharge (ESD).

3.3.2.6.5 Surface Cleanliness

Thermal control surfaces shall be cleanable to visibly clean or better.

3.3.3 Electrical Interface Requirements

3.3.3.1 Power

3.3.3.1.1 Power Bus Requirements

3.3.3.1.1.1 Electrical Interface Definitions

Electrical Interface Location: All requirements apply at the electrical interface, which is at the instrument end of the instrument-to-spacecraft bus harness connector mating surfaces.

Operational Power: Operational power is used for instrument operational modes such as Science Data Collection, Calibration, and Standby.

Peak Operational Power: Peak power is the maximum power required by an instrument. Peak power does not include transients with a duration less than 20 milliseconds.

Orbital Average Operational Power: The orbital average power is the average power utilized by an instrument over any one-orbit period commencing with the crossing of the night-to-day terminator.

Survival-Mode Power: Survival-mode power is power required by the instrument in Survival Mode, in order to operate survival heaters.

Safe-Mode Power: Safe-mode power is the power required by the instrument in instrument safe mode.

Launch-Phase Power: Launch-phase power is the power required by the instrument in launch phase.

3.3.3.1.1.2 Power Allocation

The Spacecraft will provide suitable power harnesses to support the allocated power levels specified at the instrument interface.

This section specifies the characteristics, connections, and control of the Spacecraft power provided to the instrument and requirements at this interface.

3.3.3.1.1.2.1 OLI Power Allocations

3.3.3.1.1.2.1.1 Operational Average Power Allocation

The orbital average OLI power consumed in operational modes shall be less than 250W (TBR).

3.3.3.1.1.2.1.2 Operational Peak Power Allocation

The peak OLI power consumed in operational modes shall be less than 400W (TBR).

3.3.3.1.1.2.1.3 Survival Power Allocation

The OLI power consumed in survival mode shall be less than 150W (TBR).

The OLI survival heaters shall be sized using an assumed minimum spacecraft bus voltage of 25 V.

3.3.3.1.1.2.1.4 Launch-phase Power Allocation

The OLI power consumed in launch phase shall not exceed the survival mode power allocation.

3.3.3.1.1.2.1.5 Power Interface Allocation

The number of power interfaces used by the OLI shall be consistent with the number allocated in the ICD.

Power Bus connections and power profiles for all OLI modes will be provided by the OLI contractor and documented in the ICD.

If the OLI power requirements vary as a function of orbit position, that duty cycle will be supplied by the OLI contractor and documented in the ICD.

3.3.3.1.1.2.2 TIRS Power Allocations

3.3.3.1.1.2.2.1 Operational Average Power Allocation

The orbital average TIRS power consumed in operational modes shall be less than 250W (TBR).

3.3.3.1.1.2.2.2 Operational Peak Power Allocation

The peak TIRS power consumed in operational modes shall be less than 400W (TBR).

3.3.3.1.1.2.2.3 Survival Power Allocation

The TIRS power consumed in survival mode shall be less than 150W (TBR).

The TIRS survival heaters shall be sized using an assumed minimum spacecraft bus voltage of 25 V.

3.3.3.1.1.2.2.4 Launch-phase Power Allocation

The TIRS power consumed in launch phase shall not exceed the survival mode power allocation.

3.3.3.1.1.2.2.5 Power Interface Allocation

The number of power interfaces used by the TIRS shall be consistent with the number allocated in the ICD.

Power Bus connections and power profiles for all TIRS modes will be provided by the TIRS provider and documented in the ICD.

If the TIRS power requirements vary as a function of orbit position, that duty cycle will be supplied by the TIRS provider and documented in the ICD.

3.3.3.1.1.2.3 I-SSR Power Allocations

3.3.3.1.1.2.3.1 Operational Average Power Allocation

The orbital average I-SSR power consumed in operational modes shall be less than 200W (TBR).

3.3.3.1.1.2.3.2 Operational Peak Power Allocation

The peak I-SSR power consumed in operational modes shall be less than 300W (TBR).

3.3.3.1.1.2.3.3 Survival Power Allocation

The I-SSR power consumed in survival mode shall be less than 100W (TBR).

The I-SSR survival heaters shall be sized using an assumed minimum spacecraft bus voltage of 25 V.

3.3.3.1.1.2.3.4 Launch-phase Power Allocation

The I-SSR power consumed in launch phase shall not exceed the survival mode power allocation.

3.3.3.1.1.2.3.5 Power Interface Allocation

The number of power interfaces used by the I-SSR shall be consistent with the number allocated in the ICD.

Power Bus connections and power profiles for all I-SSR modes will be provided by the I-SSR contractor and documented in the ICD.

3.3.3.1.1.3 Power Control

3.3.3.1.1.3.1 Power Connections

Three supply circuit types shall be provided by the spacecraft, with specific allocations by instrument listed in the ICD:

a) An operational power connection made through an appropriately-sized overcurrent protection device and switch, both on the spacecraft side of the interface

b) A power connection (survival heater bus) made through an appropriately-sized overcurrent protection device and a switch, both on the spacecraft side of the interface

c) A bus or set of isolated power services (safety bus) to supply power for safety-related functions such as explosive bolts, thermal release mechanisms, etc.

Each power interface shall consist of redundant two (isolated) power feeds routed via two separate connectors. These connections will be designated as power feeds A and B.

The nominal and maximum load currents for each power interface line, for each instrument mode, shall be provided by the instrument contractor and documented in the ICD.

The state of primary and redundant power supply during normal operations shall be identified in the instrument telemetry.

If the power configuration is totally under the control of the spacecraft, no additional power status telemetry is needed from the instrument.

3.3.3.1.1.3.2 Power Application

In the absence of a fault (hardware, software, or operator) on either power feed (i.e., an open fuse), the spacecraft shall apply power to neither operational power feed (instrument OFF) or a single operational power feed (instrument ON), but never to both operational power feeds simultaneously.

3.3.3.1.1.3.3 Power Fault Tolerance

The instrument and spacecraft shall not propagate a single fault occurring on either the A or B power interface circuit, on either side of the interface, to the redundant interface or instrument.

3.3.3.1.1.3.4 Instrument Heater Power Separation

Instrument survival heaters and operational heaters shall be separate and distinct, using separate electrical control, operating independently of each other.

3.3.3.1.1.3.5 Instrument Internal Power

Usage and distribution of primary power shall be compatible with system and subsystem Electromagnetic Compatibility (EMC) and magnetic field performance requirements.

Secondary power distribution to power components shall be compatible with system and subsystem EMC performance requirements.

3.3.3.1.1.3.6 Instrument External (Spacecraft) Power

Instruments shall be designed to operate from a 28 +6, -6 volt dc, negative ground, unregulated power subsystem.

The spacecraft shall be able to remove bus power to all instruments if the spacecraft power system indicates an emergency energy imbalance. This (removal of power) will not apply to survival heaters unless survival of the spacecraft is at stake.

All instrument components shall remain undamaged when subjected to gradual ramp up monotonically (as low as 1 volt per minute) of voltage in the range from 0-22 volts, for a duration not exceeding 10 seconds.

3.3.3.1.1.3.7 Unannounced Removal of Power

Excluding the thermal effects of removing instrument power, unannounced removal of power shall not cause damage or degraded performance (following re-application of power) to the instrument.

The exclusion refers specifically to the fact that unannounced removal of ALL power (operational and survival) for an indefinite period could have permanent detrimental thermal effects.

3.3.3.1.1.4 Electrical Power Interface Requirements

See the LDCM Environmental Verification Requirements document for details on the operational bus electrical power interface environment.

3.3.3.1.1.4.1 Impedance

The power bus impedance will be documented in the ICD.

The Q and impedance of the input filters of the instrument components will be documented in the ICD.

3.3.3.1.1.4.2 Survival Heater Bus

The spacecraft shall provide to the instruments power for survival heaters, meeting the same voltage range requirements as the main 28 volt bus.

Instrument design shall be such that having both primary and redundant survival heater circuits enabled does not violate any thermal or power requirement.

Note: Just because both survival circuits are enabled it does not mean that both circuits are drawing current. Since either circuit has to be able to meet the thermal requirements, if both circuits are drawing current, the instantaneous power drawn would exceed the allowed maximum by a factor of 2.

Survival power shall be used within the instrument only for resistive heaters (and associated thermal control device) which maintain the instrument at minimum turn-on temperature when the main power bus is disconnected from the instrument.

Note: "minimum turn-on" refers to the temperature at which the instrument can be sustained indefinitely without degradation in performance, once operational power has been restored and a turn-on sequence followed. The initial application of operational power by the spacecraft (turn-on) can be made at this 'minimum turn-on' temperature. Restoration of full operational status will likely involve a sequence of events following that initial turn-on, and may involve intermediate temperature constraints which must be observed.

The instrument contractor will identify (for documentation in the ICD) if more than 2 circuits are required (1 primary and 1 redundant).

The instrument shall provide thermal control of the survival heaters which is single-fault tolerant against both excessive and insufficient application of heat, and document the extent of the redundancy in the ICD.

The thermal control arrangement is intended to protect the spacecraft from excessive current drain by the instrument if the control fails ON, and to protect the instrument from becoming too cold if the control fails OFF. Whether parallel redundancy, series redundancy, or both is needed depends on the current drain, allowable instrument temperatures, and other factors.

Survival heater circuit impedance will be documented in the ICD.

The survival heaters shall be functionally redundant.

Survival heater power buses shall be electrically isolated from each other, from other instrument thermal control, from chassis, and shall have independent power returns.

The spacecraft shall ensure that both the primary and redundant survival heater circuits are normally enabled on-orbit when an instrument is off.

However, even the survival heaters may be turned off in the event of an emergency where the survival of the spacecraft is in jeopardy.

3.3.3.1.1.4.2.1 Safety Bus Operation

The spacecraft will turn on the safety bus during those periods where it is intended to be used for safety critical activities. The primary and redundant safety bus power may or may not be on at the same time, depending on spacecraft operations.

The instrument design shall not rely on presence of the Safety Bus at any time other than for initial activation of safety-critical items.

3.3.3.1.2 Grounds, Returns, and References

3.3.3.1.2.1 Grounding Responsibility

The spacecraft shall employ a single-point-ground configuration.

The spacecraft contractor shall document the observatory grounding scheme in the LDCM Observatory Electrical Requirements Document.

All interfaces from the instrument components to the spacecraft shall be documented in the ICD.

3.3.3.1.2.2 External Ground Tie Point

Each instrument component will identify an external chassis ground tie point to be used for external connections while the instrument is being moved. This will be documented in the MID. This point may be the same point used as the connection point to the spacecraft common ground path.

3.3.3.1.2.3 Thermal Blanket Grounding

All thermal blanket layers shall be grounded.

3.3.3.1.3 Electrical Harnesses and Connectors

3.3.3.1.3.1 Electrical Harnesses

3.3.3.1.3.1.1 Harness Wiring Requirements

Instrument power harnesses, within the instrument and within the spacecraft harness, shall be appropriately sized to support the peak allocated power levels and spacecraft fusing.

To the extent practical, power and signal circuits shall utilize separate connectors.

Pyro power shall utilize connectors separate from those utilized for any other purpose.

3.3.3.1.3.1.2 Harnesses Provider

All harnessing used on the spacecraft to connect the spacecraft to the instrument will be provided by the instrument contractor.

Intra-instrument harnessing, exterior to the instrument housing and connecting different parts of a single-unit instrument, or different parts of a multiple-assembly instrument mounted on a single baseplate, will be provided by the instrument contractor.

3.3.3.1.3.1.3 Harness Documentation

Harnesses, connectors, ground straps, and associated service loops will be documented in the ICD, including all requirements for harness construction, pin-to-pin wiring, cable type, etc.

3.3.3.1.3.1.4 Harness Tie Points

The provider and the locations of harness tie points will be an agreement between the instrument contractor and the spacecraft contractor, and documented in the ICD.

3.3.3.1.3.2 Electrical Connectors

3.3.3.1.3.2.1 General Considerations

Primary and redundant connectors shall be differentiated by clearly marking all boxes and cables.

The instrument contractor will provide two sets of mated pairs of interface connectors for each instrument.

The instrument contractor will provide static-discharging connector covers, delivered in-place with the instrument.

The instrument interface mating connectors dimensions and locations will be documented in the ICD.

For instrument connections to the spacecraft harness, there shall be adequate clearance around the outside of mated connectors so that there is no need for "blind mate/demates" or a need for removing adjacent instruments in order to mate or demate a harness connection.

All spacecraft connectors for all instrument connections shall have recessed contacts (e.g. female) to minimize inadvertent contact when the instrument is not mated.

Provision of clearance around the outside of connectors is the responsibility of the spacecraft contractor.

Captive covers shall be installed for all instrument connectors that are not mated to harnesses or flight plugs.

All connectors that are not used for flight or for EMI/EMC testing shall be covered with EMI tight covers.

3.3.3.1.3.2.2 Connector Location and Types

Connectors shall be located on the anti-cold-space side (sun side) of the instrument, except in those cases where local conflicts exist on the sun side, and that exception is documented in the ICD.

Connector locations, types, and orientations will be documented in the ICD.

3.3.3.1.3.2.3 Keying

Connectors shall be different sizes, different types, different orientation, color coded or uniquely keyed (in order of preference) to the extent feasible in order to prevent improper connection.

3.3.3.1.3.2.4 Flight Plugs

Flight plugs requiring installation prior to launch shall be capable of being installed at the Spacecraft level.

Flight plugs and their locations will be documented in the ICD.

3.3.3.1.3.2.5 Buffer Connectors and Connector Savers

Instrument buffer connectors and connector savers shall be utilized prior to spacecraft-level system tests.

Note: The intention is to mitigate risk of bent pins or otherwise damaged flight connectors.

3.3.3.1.3.2.6 Test Connectors:

Test point interface circuit and equipment failures shall not be capable of propagating failures into the instrument. This includes credible failures in GSE connected externally to the test point interface connectors.

Captive flight quality and flight capable test connector covers shall be installed whenever the test connector is not in use.

Test connectors and their locations will be documented in the ICD.

3.3.3.1.3.3 Breakout Boxes

Test-tees, interrupt boxes, and breakout boxes for instrument-to-spacecraft interfaces will be provided by spacecraft contractor.

3.3.3.2 Command and Data Handling

Unless specified otherwise, the requirements in this section shall apply to all Command and Data Handling (C&DH) interfaces.

3.3.3.2.1 Electrical Interfaces

All electrical interfaces except test point interfaces shall be functionally redundant.

The electrical interfaces (see Figures 3.3.3.2.1-1 and 3.3.3.2.1-2) include the following. The requirements for each interface are identified later in this Section:

High Speed Science Data Bus (HSSDB)

High Speed I-SSR Data Bus (HSIDB)

1553 Command and Data Bus

1 Hz Time of Day Pulse

Pulse Command Interface

Safety Bus

Bilevel Telemetry Interface

Passive Analog Telemetry Interface

Operational Power Bus

Survival Heater Power Bus

Grounding Interface

Test Point Interface.

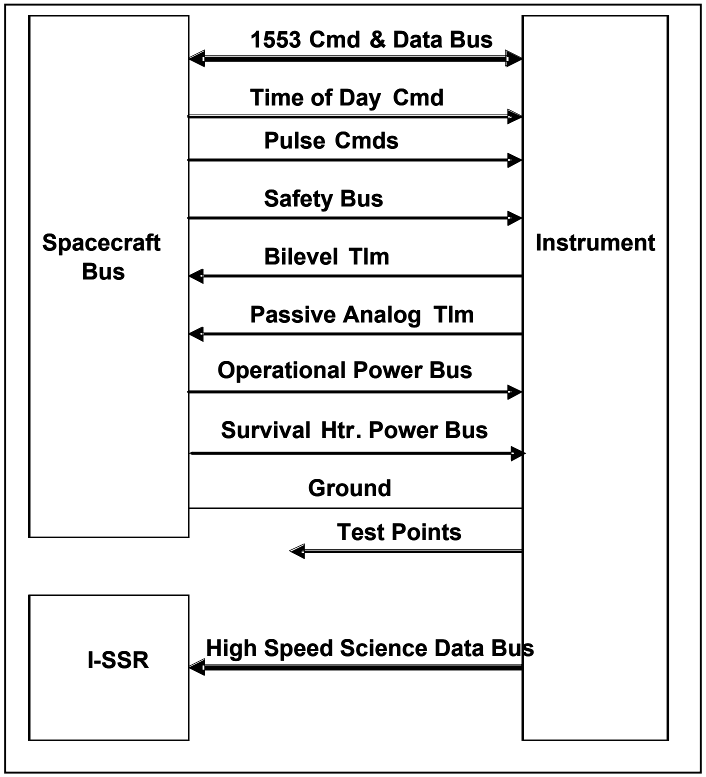

Figure 3.3.3.2.1-1. Spacecraft to Instrument/Instrument to I-SSR Electrical Interfaces [TBR]

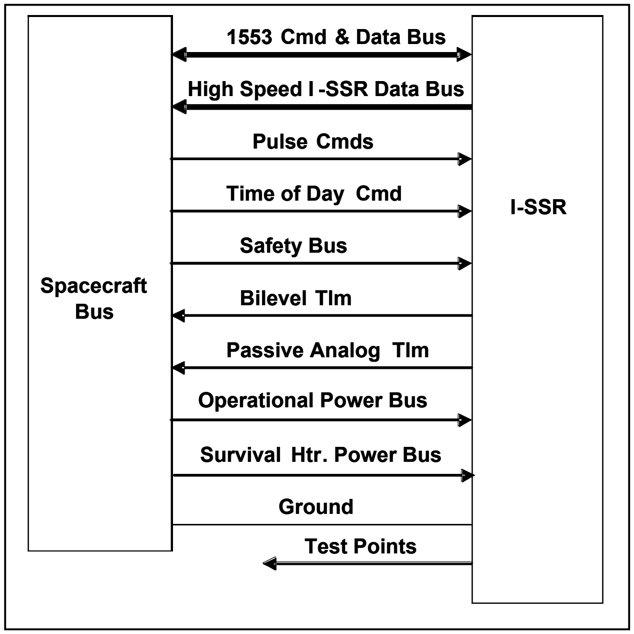

Figure 3.3.3.2.1-2. Spacecraft to I-SSR Electrical Interfaces [TBR]

3.3.3.2.1.1 Interface Fault Tolerance

A single fault on either the spacecraft side of the interface or the instrument side of the interface shall not prevent the full and complete digital data transfer needed to fulfill mission requirements.

3.3.3.2.2 Data Bus Requirements

3.3.3.2.2.1 Bus Functions

Spacecraft, Instruments and the I-SSR shall interface to the MIL-STD-1553 data bus.

Instruments shall interface to the High Speed Science Data Bus (HSSDB).

The I-SSR shall interface to the High Speed Science Data Bus and the High Speed I-SSR Data Bus (HSIDB).

The following functions, where appropriate, shall be provided between the spacecraft and the instrument components (including the I-SSR).

a) Spacecraft to instrument transfers consisting of:

- real-time ground commands
- stored commands
- memory loads
- state of health indications
- ancillary data (e.g., time code, satellite ephemeris and attitude)

b) Instrument to spacecraft transfers consisting of:

- instrument health and status telemetry
- instrument transition to safe mode indicator
- instrument diagnostic data
- memory dumps
- survival mode temperatures (not part of the data bus)

c) Instrument to I-SSR transfers consisting of:

- mission data, including ancillary data received from spacecraft

3.3.3.2.3 Interface Characteristics

3.3.3.2.3.1 High Speed Science Data Bus (HSSDB)

The HSSDB is defined as the set of interfaces from the OLI instrument and the TIRS instrument to the I-SSR.

Instrument Mission Data shall be transferred to the I-SSR via the High Speed Science Data Bus.

The details of the HSSDB will be documented in the LDCM Instruments to I-SSR ICD.

The HSSDB may consist of a single or multiple physical interfaces, and any necessary handshaking or flow control to manage the interface.

3.3.3.2.3.1.1 HSSDB Data Rate

TBD

3.3.3.2.3.1.2 HSSDB Physical Layer

TBD

3.3.3.2.3.1.3 HSSDB Data Format

The HSSDB shall include the instrument data and information on data type and data timing (timestamp) as necessary to support file operations of the I-SSR.

3.3.3.2.3.2 High Speed I-SSR Data Bus (HSIDB)

The HSIDB is defined as the interface from the I-SSR to the spacecraft X-band system.

The HSIDB shall consist of three independent channels that each support a realtime or playback data stream.

The HSIDB may consist of a single or multiple physical interfaces, and any necessary handshaking or flow control to manage the interface.

The details of the HSIDB will be documented in the LDCM Spacecraft to I-SSR ICD.

3.3.3.2.3.2.1 HSIDB Data Rate

The combined output rate of Mission Data and diagnostic data on the Instrument to I-SSR interface shall not exceed the 230 Mbps (TBR) per channel for each of the three independent output channels, including all CCSDS packetization, framing, and coding overhead.

Note: When the data rate allocation in the LDCM Instruments to I-SSR ICD is finalized it will supersede this number.

3.3.3.2.3.2.2 HSIDB Physical layer

TBD

3.3.3.2.3.2.3 HSIDB Data Format

The HSIDB data shall be compliant with CCSDS recommendation 131.0-B-1 Channel Access Data Units (CADUs).

The CADUs shall contain randomized codeblocks encoded with LDPC per CCSDS experimental specification 131.1-O-1.

Convolutional coding shall not be applied.

3.3.3.2.3.3 MIL-STD-1553 Characteristics

3.3.3.2.3.3.1 Electrical Interface

The spacecraft contractor will define the bus implementation characteristics in the LDCM Observatory 1553 Bus ICD.

Unspecified parameters will not be assumed or assigned by the instrument contractor without concurrence from the spacecraft contractor, at which time they are to be documented in the LDCM Observatory 1553 Bus ICD.

3.3.3.2.3.4 Pulse Commands

Pulse commands from the spacecraft shall not be used for functions which could be accomplished by the instrument itself, or by command from the spacecraft via the data bus.

The primary means of commanding the instrument is through the command & data interface. If necessary, and as approved by the spacecraft contractor and documented in the ICD, selected commands may utilize pulse (relay driving) commands, having the characteristics given below.

Instrument discrete pulse commands shall have redundant interfaces per function, one primary, and one redundant, each controlled by one wire pair (command/return).

The spacecraft contractor shall define the pulse command characteristics in the ICD.

3.3.3.2.3.5 Time of Day Pulse

The spacecraft shall provide a 1 Hz Time of Day pulse to indicate the point in time at which to apply the time code which was previously transmitted over the data bus.

The instrument shall utilize the rising edge of the Time of Day pulse, together with the time code data, in order to establish the time reference for instrument data.

The spacecraft contractor shall define the Time of Day pulse command characteristics in the ICD.

The spacecraft shall issue the Time of Day pulse rising edge (non-inverting side of differential interface) within 5 microseconds (TBR) of each spacecraft 1-second time occurrence.

3.3.3.2.3.6 Synchronization

Where instruments require synchronization to each other that is more precise than the onboard time correlation requirement, the spacecraft shall provide a means whereby synchronization can be accomplished via the data bus interface, as detailed in the ICD for the affected instrument.

3.3.3.2.4 Instrument Commands and Data Load

The standard means of transmitting commands and data loads from the spacecraft to the instrument shall be via the 1553 data bus.

The spacecraft shall, through the MIL-STD-1553 bus, deliver the instrument command and data load to the specified instrument RT-receive address/sub-address by conducting BC-to-RT Transfers or RT-to-RT Transfers (from a spacecraft RT to an instrument RT).

The spacecraft shall provide discrete commands for instrument operational and survival heater power switching, fault recovery, and squib functions as necessary.

The spacecraft shall provide auxiliary data and spacecraft ephemeris and attitude data, as appropriate and detailed in the ICD.

All commands to be transferred to the instrument via the point-to-point (discrete) command interfaces and the command and telemetry bus, will be documented in the ICD.

3.3.3.2.4.1 Commands

The instrument contractors will provide command information to the spacecraft contractor for inclusion in the LDCM Observatory 1553 Bus ICD.

Commands to instruments from the spacecraft will be documented in the LDCM Observatory 1553 Bus ICD.

No single point failure shall prevent the instrument components from receiving commands.

3.3.3.2.5 Instrument Health and Status Telemetry

The instrument contractors will provide instrument health and status telemetry information to the spacecraft contractor for inclusion in the LDCM Observatory 1553 Bus ICD.

Instrument health and status telemetry will be documented in the LDCM Observatory 1553 Bus ICD.

No single point failure shall prevent spacecraft access to critical telemetry points.

3.3.3.2.5.1 Point-to-Point Telemetry

Point-to-point telemetry is intended to represent "static" information (for example: relay status associated with pulse commands where knowledge of the relay position is required even when the instrument is off) such that sampling rates in the seconds, or tens of seconds, is adequate.

All spacecraft-instrument point-to-point telemetry interfaces will be documented in the ICD.

Instrument component point-to-point telemetry shall include redundant passive analog temperature measurement devices at a number of locations per instrument as documented in the ICD.

Redundancy may be accomplished by thermally overlapping regions for non-critical measurements. These analog lines are separate and in addition to any state of health (SOH) input being transmitted over the command and data interface and are intended to provide insight during periods when the instrument operational power is not present; therefore, excitation of the passive analog temperature measurement devices is provided by the spacecraft.

3.3.3.2.5.2 Command Verification

Receipt of individual commands via the Command & Data bus shall be verifiable via instrument Health and Status telemetry.

Receipt of individual Pulse commands shall be directly verifiable via Point-to-Point Telemetry or some other means.

3.3.3.2.5.3 Instrument Memory Dump

Instrument Memory Dump data shall be transferred to the spacecraft C&DH via the 1553 data bus as specified in the ICD.

3.3.3.2.5.4 Telemetry Monitor

Any requirement for the spacecraft to monitor selected telemetry points (including telemetry from the command and telemetry bus and point-to-point interfaces) and initiate action to the instrument based upon a pre-determined telemetry state will be negotiated with the spacecraft contractor and documented in the ICD.

All instrument telemetry points to be monitored by the spacecraft, for spacecraft action, will be documented in the ICD, along with the action to be taken and the algorithm for such action, as specified by the instrument contractor.

The Spacecraft Telemetry Monitor (TMON) function shall perform threshold checking on specific data items as described in the ICD.

The Spacecraft Telemetry Monitor (TMON) function shall be capable of activating a stored command sequence when errors are detected (i.e. a defined threshold is exceeded).

The TMON data thresholds shall be defined in tables in the flight software.

The TMON tables shall be modifiable by the ground via a Memory Load operation.

The TMON function shall compare the collected data with the predefined limits defined in the tables.

Any payload telemetry parameter that requires monitoring by the spacecraft shall be placed in a TMON packet message.

The format description of this TMON packet shall be defined in the ICD.

The instrument contractors shall provide to the spacecraft contractor the autonomous fault response algorithm for each TMON monitor point.

3.3.3.2.6 Command & Data Interface Test Packets

The instrument shall be capable of generating and transmitting, on command, a continuous sequence of packets containing a fixed data pattern.

Instrument test packets shall have a unique APID.

Test Packet APIDs, patterns and lengths will be documented in the ICD.

3.4 ENVIRONMENTAL CONDITIONS

This section specifies the environment characteristics in the presence of which the spacecraft and the instrument components (referred to as space equipment in this section) must meet all other requirements.

3.4.1 Radiation Environment

The space equipment shall be capable of meeting all performance requirements for the ionization and displacement damage levels produced by the natural radiation environments for their operational orbits for the operational lifetime of the mission.

3.4.2 Meteoroid and Debris Environments

Space equipment and materials that are directly exposed to free space, such as cables, propulsion lines, pressurized tanks, and sensor optics, shall be designed to meet reliability requirements to remain operable within their performance specifications over the mission lifetime in the meteoroid and space debris environments in the operational orbit.

3.4.3 Spacecraft Magnetic Fields

The space equipment shall not exhibit any malfunction, degradation of performance or deviation from the specified indications beyond the tolerances indicated in their individual equipment specifications as a result of being exposed to DC magnetic levels not exceeding the natural Earth field at sea level. (TBR)

3.4.4 Atomic Oxygen

The space equipment shall meet performance requirements during exposure to atomic oxygen (AO) experienced over the mission lifetime in the environments in the operational orbit.

3.4.5 Spacecraft Charging from All Sources

The space equipment shall operate without performance degradation due to the surface charging, bulk charging, and deep charging environment.

3.4.6 Launch Environment

The baseline LDCM launch vehicle is a Delta-II.

The LDCM spacecraft and instrument components shall be compatible with the launch environments as specified in the LDCM Launch Vehicle ICD.

3.5 DESIGN AND CONSTRUCTION

3.5.1 Instrument Electrical Power Interface Design Requirements

The instruments shall have EMI input filters installed on the instrument side of the power interface.

The filters shall provide both common-mode and differential-mode filtering.

3.5.2 Instrument Mechanical Interface Design Requirements

3.5.2.1 Component Stiffness

Except as permitted below, each separately-mounted instrument component, configured for launch, shall have a fixed-base fundamental resonant mode frequency of greater than 50 Hz (TBR).

Fixed-base is defined as follows: Each mounting point shall be constrained in those translational degrees of freedom which are rigidly attached to the spacecraft and shall be free in those translational degrees of freedom for which kinematic mounts or flexures provide flexibility.

The fundamental resonant mode frequency for an instrument in its on-orbit configuration shall be 6 Hz (TBR) or greater.

3.5.2.2 Instrument Mechanisms

All instrument mechanisms which require restraint during launch shall be caged during launch without requiring power to maintain the caged condition.

Instrument mechanisms which require caging and/or uncaging during test and launch site operations shall be capable of being caged or uncaged by command and by manual actuation of accessible locking/unlocking devices.

Instrument mechanisms which require uncaging and/or caging on-orbit shall be capable of being caged and uncaged by command.

3.5.2.3 Uncompensated Momentum

Each instrument having movable components shall not exceed an uncompensated momentum contribution of +/- 0.5 N-m-sec (TBR) per axis.

The typical uncompensated momentum contribution of the instrument will be documented in the instrument ICD.

3.5.2.4 Instrument Disturbance Allocations

Early estimates of gimbaled masses, inertias, and cg will be provided to the spacecraft contractor to permit sizing the control components to meet pointing and stability requirements.

3.5.2.4.1 Periodic Disturbance Torque Limits

The instrument contractor will provide, in electronic format, time/magnitude plots of their disturbances, for decomposition by the spacecraft contractor, of the sum of the instrument-induced periodic disturbance torques, in order to produce the corresponding magnitude spectrum.

The magnitude of the periodic disturbance torque, including the torque resulting from linear forces reacting from the instrument to the spacecraft) shall be in the acceptable range of Figure 3.5.2.4.1-1 for all frequencies.

The instrument ICD will specify the predicted disturbance torque contributions to the spacecraft, if any.

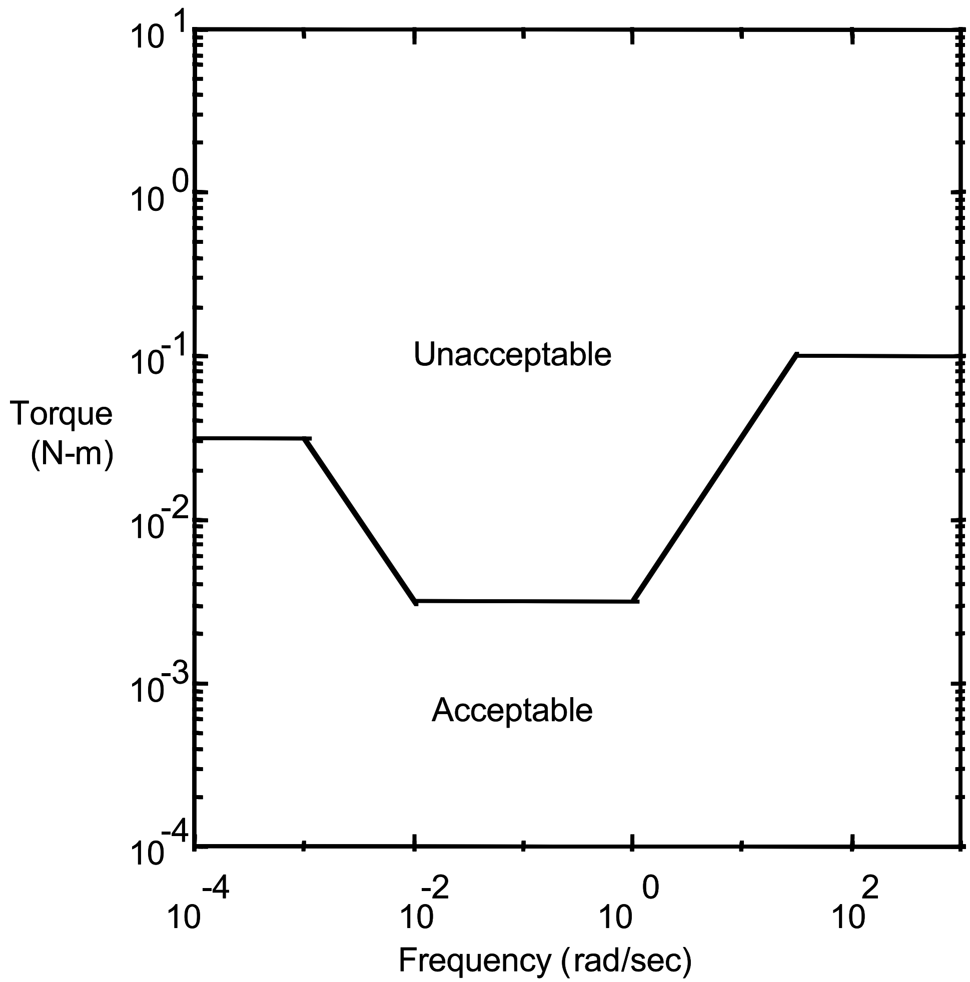

Figure 3.5.2.4.1-1. Allowed Transmitted Torque (TBR)

Table 3.5.2.4.1-1. Allowable Transmitted Torque Transition Points (TBR)

Frequency (rad/sec)	Torque (N-m)
< 0.001	0.03
0.01	0.00

1.0	0.00
> 33.3	0.1

3.5.2.4.2 Constant Disturbance Torque Limits

Instrument-induced constant disturbances of the same polarity, separated by more than 200 seconds, shall not exceed the torque limit defined in Figure 3.5.2.4.2-1 if the duration of application is in excess of 10 seconds. For constant torques of 10 seconds duration or less, the impulse limit is 0.04 N-m-s (TBR).

For constant torques of 400 seconds duration or more, the torque limit is maintained at the 400 second limit shown in Figure 3.5.2.4.2-1.

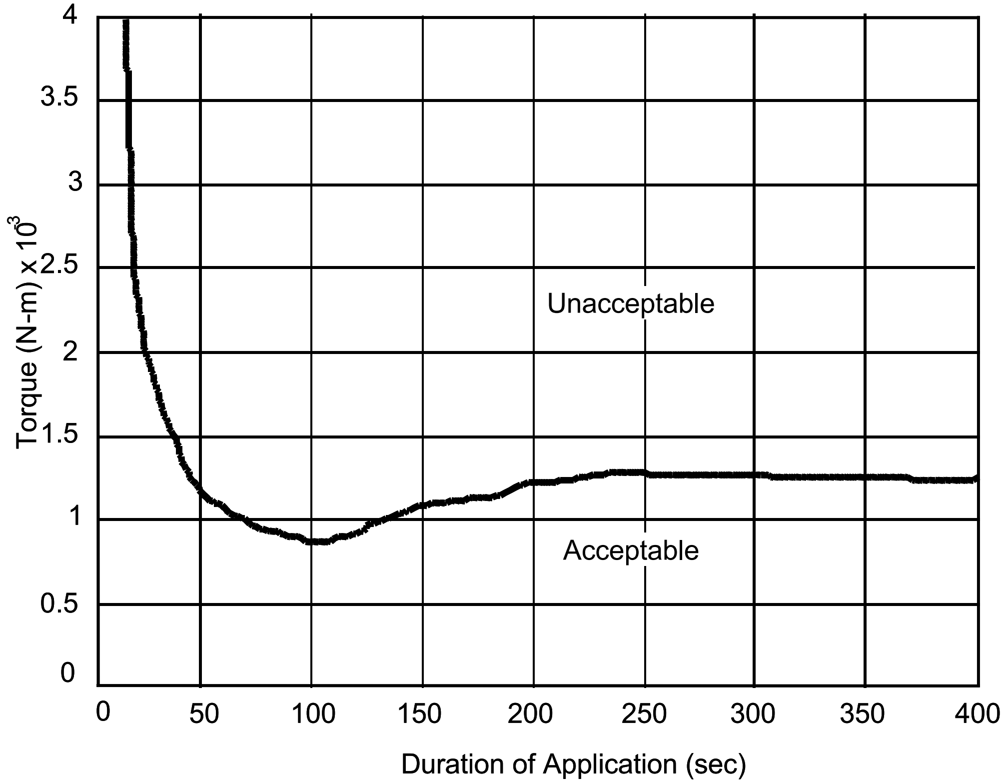

Figure 3.5.2.4.2-1. Constant Torque vs. Duration of Application (TBR)

3.5.2.4.3 Disturbance Torque Limits for Linear Forces

The same requirements specified above for constant and periodic torques shall apply when linear forces are converted to torques, assuming a moment arm of 2 m for motion along the pitch or yaw axes and 3 m for motion along the roll axis.

The torques about the spacecraft CM resulting from instrument linear forces will be documented in the instrument ICD.

3.5.2.4.4 Spacecraft Non-Operational Deployment Disturbance

The on-orbit non-operational Spacecraft disturbances produced by the uncaging or deployment of any mechanism or device shall be less than 158 N-m (TBR) at the point of attachment.

3.5.2.4.5 Torque Profile Documentation

The instrument contractor will provide the typical instrument torque versus time profile to the spacecraft contractor for documentation in the ICD.

3.5.2.4.6 Thrust Direction Definition

The instrument contractor will provide to the spacecraft contractor the magnitude and direction of net thrust, timing of expulsion events, and expulsion material resulting from the expulsion of expendables by the instrument, for documentation in the ICD.

3.5.3 Magnetics

The LDCM spacecraft and instruments shall minimize the use of magnetic materials where possible.

If magnets are inherent to the instrument design, early estimates of magnetic fields and residual magnetic dipole moments will be provided to the spacecraft contractor for documentation in the ICD.

3.5.4 Access

3.5.4.1 Access Identification

The instrument contractor will provide to the spacecraft contractor access requirements for documentation in the MID.

3.5.5 General Access

All items to be installed, removed, or replaced at the spacecraft level shall be easily accessible without disassembly of the unit.

Access requirements and clearances will be mutually agreed-upon between the spacecraft contractor and the instrument contractor.

3.5.6 Mounting/Handling

3.5.6.1 Mounting Orientation

Instrument design shall be such that the instrument is capable of being mounted to the spacecraft with the spacecraft interface in the horizontal position.

3.5.6.2 Instrument-to-Spacecraft Integration and Test Mounting

Each separately-mountable instrument component shall be capable of being installed and removed without removal of other instruments or subsystems, and without demating or removal of harness (including coax) other than for the unit being removed.

Connector access for removal and reassembly of an instrument shall be accomplished without requiring removal of any equipment.

Instrument mounting hardware shall be installed from the instrument side of the spacecraft - instrument mechanical interface.

Installation/removal of any separately-mountable component shall not require rotation during installation/removal.

3.5.6.3 Non-Flight Equipment

The instrument contractor will provide to the spacecraft contractor information on all items to be installed or removed prior to flight, for identification in the ICD.

3.5.7 Venting

Instrument contractors will provide to the spacecraft contractor the location, size, path, venting forces and impulses, direction of net thrust, and operation time of vents in the instruments for inclusion in the ICD.

The spacecraft contractor shall place the instrument such that the contamination products from the vents of one instrument cannot directly impinge on another instrument's contamination-sensitive surface nor directly enter another instrument's aperture.

3.5.8 Contamination

The contamination interface requirements will be provided to the spacecraft contractor for inclusion in the ICD.

This includes contamination sensitivity of the instrument, as well as identification and characterization of all sources of contamination that can be emitted from the instrument.

3.6 DOCUMENTATION

3.6.1 Interface Control Drawings and Documents

Each instrument developer is responsible for providing inputs to the ICDs in accordance with contractual requirements.

After award of the spacecraft integration contract, each instrument developer and the spacecraft contractor will jointly write the Interface Control Documents (ICDs) which define the details of the instrument-to-spacecraft interface and instrument accommodation information.

The spacecraft contractor will be responsible for developing and controlling the ICD except as noted otherwise.

Drawings defining/documenting the interface between the instrument and the spacecraft which are not otherwise included in the ICD will be contained in an MID controlled by the spacecraft contractor.

3.7 INTERFACE HARDWARE PROVIDERS

Interface hardware will be provided by the organization shown below.

HARDWARE	PROVIDER
Standard mounting hardware (e.g., std. fasteners, shims)	Spacecraft
Special mounting hardware (instrument-unique)	Instrument
Mounts (e.g., kinematic, flexure, etc.)	Instrument
Optically aligned component drill template	Instrument
Non-optically aligned component drill template	Instrument
Instrument optical alignment target /cube and cover	Instrument
Holding and lifting fixtures	Instrument
GSE - special, electrical and mechanical	Instrument
GSE - general, electrical and mechanical	Spacecraft
Shipping containers	Instrument
Flight connectors both sides of the electrical interface	Instrument